ROOT RESORPTION BEFORE AND AFTER ORTHODONTIC TREATMENT – A RETROSPECTIVE COMPARATIVE STUDY BETWEEN CLASS I , CLASS II DIVISION 1 MALOCCLUSION ON CLASS I SKELETAL BASE AND CLASS I , CLASS II DIVISION 1 MALOCCLUSION ON CLASS II SKELETAL BASE.

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CERTIFICATE

This is to certify that the dissertation entitled **" Root resorption before and after orthodontic treatment – A retrospective comparative study between class I, class II division 1 malocclusion on class I skeletal base and class I , class II division 1 malocclusion on class II skeletal base. "** done by **Dr. TAMILSELVI.B,** Postgraduate student (M.D.S),Orthodontics (branch V), Tamil Nadu Government Dental College and Hospital, Chennai, submitted to the Tamil Nadu Dr. M.G.R. Medical University in partial fulfillment for the M.D.S. degree examination (April 2017) is a bonafide research work carried out by her under my supervision and guidance.

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DECLARATION

I, **Dr. TAMILSELVI. B**, do hereby declare that the dissertation entitled **"ROOT RESORPTION BEFORE AND AFTER ORTHODONTIC TREATMENT – A RETROSPECTIVE COMPARATIVE STUDY BETWEEN CLASS I, CLASS II DIVISION 1 MALOCCLUSION ON CLASS I SKELETAL BASE AND CLASS I, CLASS II DIVISION 1 MALOCCLUSION ON CLASS II SKELETAL BASE"** was done in the Department of Orthodontics, TamilNadu Government Dental College & Hospital, Chennai 600003. I have utilized the facilities provided in the Government Dental College for the study in partial fulfillment of the requirements for the degree of Master of Dental Surgery in the specialty of Orthodontics and DentofacialOrthopaedics (Branch V) during the course period 2014-2017 under the conceptualization and guidance of my dissertation guide, **Prof.Dr. Sridhar Premkumar, M.D.S.** I declare that no part of the dissertation will be utilized for gaining financial assistance for research or other promotions without obtaining prior permission from the Tamil Nadu Government Dental College & Hospital.

I also declare that no part of this work will be published either in the print or electronic media except with those who have been actively involved in this dissertation work and I firmly affirm that the right to preserve or publish this work rests solely with the prior permission of the Principal, Tamil Nadu Government Dental College & Hospital, Chennai 600 003, but with the vested right that I shall be cited as the author(s)

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Signature of Head of Institution

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TRIPARTITE AGREEMENT

This agreement herein after the "Agreement" is entered into on this............... day of December 2016 between the Tamil Nadu Government Dental College and Hospital represented by its **Principal** having address at Tamil Nadu Government Dental College and Hospital, Chennai-03, (hereafter referred to as, ‟ the college‟)

And

Dr. SRIDHAR PREMKUMAR aged 47years working as professor at the college, having residence address B-3, Block 2, Jains Ashraya Phase III, Arcot road, Virugambakkam, Chennai-92. (Herein after referred to as the 'Principal investigator')

And

Dr. TAMILSELVI. B aged 30 years currently studying as postgraduate student in department of Orthodontics in Tamil Nadu Government Dental College and Hospital (Herein after referred to as the "PG/Research student and co-investigator").

Whereas the, PG/Research student as part of his curriculum undertakes to research ***"Root resorption before and after orthodontic treatment – A retrospective comparative study between class I, class II division 1 malocclusion on class I skeletal base and class I, class II division 1 malocclusion on class II skeletal base"*** for which purpose the PG/Principal investigator shall act as principal investigator and the college shall provide the requisite infrastructure based on availability and also provide facility to the PG/Research student as to the extent possible as a Co-investigator.

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8. It is agreed that as regards other aspects not covered under this agreement, but which pertain to the research undertaken by the student Researcher, under guidance from the Principal Investigator, the decision of the college shall be binding and final.
9. If any dispute arises as to the matters related or connected to this agreement herein, it shall be referred to arbitration in accordance with the provisions of the Arbitration and Conciliation Act, 1996.In witness whereof the parties hereinabove mentioned have on this the day month and year herein above mentioned set their hands to this agreement in the presence of the following two witnesses.

Principal **PG Student**

Witnesses **Student Guide**

1.
2.

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INTRODUCTION

Facial aesthetics is a key factor in overall physical attractiveness,which contributes to self-esteem. This is the main reason for patients to seekorthodontic treatment. Orthodontic treatment of malocclusion, by ensuring proper alignment of teeth, improves facial aesthetics, self-esteem, mastication,phonation, overall general and dental health.

Any medical intervention in addition to its benefits, carries some degree of complications. Orthodontics is no exception to this rule. Fortunately,the benefits the patient achieve through orthodontic treatment outweigh the potential complications.

The main complications linked to orthodontic intervention includestoothdiscoloration, decalcification, enamel fracture, root resorption, pulpdamage, gingival and periodontal complications.[1,2,3]Among all the complications, one of the most important hidden scar of orthodontic treatment is root resorption.[18] Root resorption gain importance not only due to being highly frequent with potential biological damage to the teeth, but also due to potential legal implications in daily orthodontic practice.

Root resorption becomes often a nightmare for almost every practising orthodontist.The literature indicates that patients undergoing orthodontictreatment are more likely to have root resorption.[1,3,9,21] Orthodontic treatment can be a major trigger for apical root resorption. In most cases, it is insignificant clinically and less frequently noticeable on X- rays. However, some patientsreact more severely. If the roots become too short, the teeth can become mobile or even be lost.

The etiology of root resorption is multifactorial.[9] Apart from the idiopathic causes,orthodontic related risk factors includes treatment duration,magnitude of applied force, directionof tooth movement, amount of apical displacement and method of force application.

Methods to detect root resorption includes radiological examination modes like periapical radiographs, panoramic radiograph, CBCT, and CT scans.Studies indicate that comparing vertical measurements on panoramic radiography taken at different times is sufficiently accurate to determine changes in root length.

The advantage of using panoramic imaging (OPG) is, it providessingle tomographic picture of the entire dentition, dentoalveolar bone and broad coverage of both the jaws. Panoramic radiographs are taken before and after treatment to monitor treatment situation for all patients. Hence,using OPG to detect root resorption can also avoid unnecessary radiation exposure. [39,44]

Malocclusions can be of skeletal origin or dentoalveolar origin on normal class I skeletal base. In malocclusions of skeletal origin, there is dentoalveolar compensation and hence theposition of teeth differs in skeletal (compensated) malocclusion and dentoalveolar (non-compensated) malocclusion.[48] Therefore the magnitude of tooth movement, amount of apical displacement, direction of tooth movement and treatment mechanics varies accordingly and hence, the root resorption level may also differ in compensated and non-compensated malocclusion.[50,54]

The purpose of this study is to evaluate and compare the root resorption level among compensated and non-compensated malocclusion and to find out higher risk group.

AIM AND OBJECTIVES

AIM OF THE STUDY

The aim of this retrospective study is to compare the root resorption levels between subjects with malocclusion on class I skeletal base and class II skeletal base treated with fixed appliance mechanotherapy following premolar extraction.

OBJECTIVES OF THE STUDY

- To score the root resorption level in subjects with class I malocclusion on class I skeletal base.
- To score the root resorption level in subjects with class II division 1 malocclusion on class I skeletal base.
- To score the root resorption level in subjects with class I malocclusion on class II skeletal base.
- To score the root resorption level in subjects with class II division 1 malocclusion on class II skeletal base.
- To compare the differences in levels of root resorption among class I skeletal base and class II skeletal base.
- To compare the differences in levels of root resorption among class I and class II division 1 malocclusion irrespective of skeletal base relationship.

REVIEW OF LITERATURE

Numerous studies were found in literature with respect to complications of orthodontic treatment and root resorption. The articles relating to various risk factors associated with root resorption and various methods to assess root resorption are plenty in nature. The most relevant studies are presented here.

COMPLICATIONS OF ORTHODONTIC TREATMENT

Van Beek H (2009)[33] reviewed literature and identified various complications associated with orthodontic treatment, which includes enamel damage, root resorption, periodontal damage, temporomandibular disorders, tooth devitalization, treatment failure, and relapse. The greatest risk is a failure to adequately inform the patient concerning all of the possibilities and their consequences.

Zachrisson BU (1976)[62] investigated and found that, although there are definite risks in undertaking orthodontic treatment with fixed appliances, such treatment need not cause any appreciable damage when accepted orthodontic principles are followed in cooperative patients with good oral hygiene and regular fluoride treatment. On the other hand, when these principles are neglected, the damage may be considerable and the benefits from orthodontic treatment questionable.

Zachrisson et al (1980)[63] conducted a study of clinical assessment of enamel cracks (prevalence, localization, expression, direction) in three groups of adolescents representing debonded, debanded, and orthodontically untreated teeth by using fibre optic transillumination. The findings indicated that enamel cracks were extremely common in all three groups. Most cracks were not very prominent and could easily be overlooked on routine clinical examination. The marked cracks were observed mostly on maxillary canines and central incisors in all groups. Horizontal cracks were noted on maxillary and mandibular central incisors. Hence, whenever pronounced vertical cracks or many horizontal cracks are observed, the bonding/debonding technique should be re-evaluated.

Sadowsky C, BeGole EA (1981)[64] evaluated the periodontal health of a group of ninety-six patients who had received comprehensive fixed-appliance orthodontic treatment during adolescence between 12 and 35 year. Comparisons were made with a group of 103 adults who were similar with regard to race, sex, age, socioeconomic status, dental awareness, and oral hygiene status but had malocclusions that had not been orthodontically treated. They found that the orthodontic group had a greater prevalence of mild to moderate periodontal disease in the maxillary posterior and mandibular anterior regions of the mouth, as compared to the control group.

Gorelick L et al (1982)[66] studied the incidence and severity of white spots after a full term of orthodontic treatment among patients in the separate private practices of two of the authors. The incidence of white spots among patients treated by a multibonded technique was recorded at the time of debonding. It was found that individual teeth, banded or bonded, exhibited significantly more white spot formation than was found in the control group. They found that the labiogingival area of the maxillary lateral incisors had the highest incidence of white spot and lowest was in the maxillary posterior segment.

Bass JK, Fine H, Cisneros GJ (1993)[67] conducted a study to determine if standard orthodontic therapy can sensitize patients to nickel and to assess gingival response to nickel-containing orthodontic appliances in patients who are nickel sensitive before treatment. Nickel sensitivity patch tests were conducted to confirm hypersensitivity to nickel. They found two patients converted from an initial negative patch test to a positive test and hence there may be a risk of sensitizing patients to nickel with long-term exposure to nickel-containing appliances as occurs in routine orthodontic therapy.

ROOT RESORPTION AND ITS CAUSES

Ketcham (1927)[1] conducted a radiographic survey of 385 treated cases and he found that 22 % of 224 patients had experienced some degrees of root resorption during orthodontic treatment. His study have shown that maxillary teeth were affected twice as frequently as mandibular teeth and that more resorption occurred in cases treated with ribbon arch or pin and tube appliances than in cases treated with labial or lingual arches.

Robert W. Deshields (1969)[2] conducted a study to determine whether the frequency and severity of root resorption varies with treatment mechanics or the amount of tooth movement produced in treatment. He evaluated the levels of root resorption in 52 subjects with class II division 1 malocclusion who were treated non extraction with edgewise mechanics. He found that root resorption occurs in nearly all treated orthodontic patients. Maxillary incisors were commonly affected by orthodontic treatment. He also found that the severity of root resorption was partially related to treatment duration and mechanics used and apical movement is a suspected cause of apical resorption.

K.Reitan (1974)[3] conducted a study of experimental extrusion, intrusion and tipping movement of human premolars. The results revealed that root resorption occurs in majority of cases. The resorbed root substance, except shortened apical poprtion, will be reconstructed by cellular cementum. They found that the apical root resorption does not prevent further development of roots in which there is fairly thick predentin layer.

Lars Goldson (1975)[4] conducted a study to evaluate root resorption during Begg treatment. Forty-two patients consecutively treated by the Begg method, all of whose first premolars had been extracted before orthodontic treatment, were examined roentgenologically by an intraoral technique on three to four occasions. They found that the resorption level increased more for the upper central incisors, which were subjected to root torque, than for the upper lateral incisors and the lower premolars showed the lowest incidence of root resorption.

Brita Ohm Linge, Leif Linge (1983)[5] studied the incidence and extent of apical root resorption in maxillary incisors radiographically in 719 consecutively treated orthodontic patients. They found significantly more root resorption in patients starting treatment after ii years of age than patients starting earlier. They have also found that fixed appliances caused significantly more apical root resorption than removable appliances.

Remington , Joondeph D et al (1989)[6] conducted a study to evaluate the long-term status of teeth that had undergone root resorption during active orthodontic treatment. They found that the maxillary incisors were affected more frequently and to a greater degree than the rest of the teeth during active treatment.

Kaley J, phillips.C (1991)[7] conducted a study of 200 consecutively debanded patients receiving comprehensive orthodontic treatment with the edgewise appliance. They found six severe resorption (greater than one-quarter of the root length) of both maxillary central incisors in 6 (3%) cases. For other teeth, resorption of this extent occurred in less than 1% of the patients. They found significantly more resorption among class III patients.

Leif Linge (1991)[8] carried out a multivariate analysis of patient characteristics and clinical variables with the maximum single maxillary incisor apical root resorption for each patient as the dependent variable. Variables found to contribute significantly to apical root resorption were overjet, history of trauma to maxillary incisors before initiation of treatment, time of treatment with rectangular arch wires, time of treatment with Class II elastics, lip/tongue dysfunction, and/or history of finger-sucking habits persisting beyond the age of 7 years, and impacted maxillary canines to be corrected orthodontically.

Brezniak N1, Wasserstein A (1993)[9] reviewed literature on apical root resorption. They found that the permanent teeth have the potential to clinically undergo significant external root resorption when affected by several stimuli. The extent of treatment duration and mechanical factors definitely influence root resorption.

Inger (1995)[10] found in his study that: (1) there is a strong connection between various dental morphological characteristics, such as invagination, length of root, and root shapes, especially taurodontism, and the tendency to root resorption during orthodontic treatment; (2) there is a connection between anomalies in the dentition, particularly ectopia and agenesis, and the tendency to root resorption during orthodontic treatment; (3) there seems to be a connection between the pattern of resorption in the primary dentition and the tendency to root resorption in the permanent dentition following orthodontic treatment; (4) girls are more susceptible to root resorption during orthodontic treatment than boys.

David Mirabella and John Artun (1995)[11] conducted a study to evaluate prevalence and severity of root resorption of maxillary anterior teeth in a large sample of adult orthodontic patients to test the hypothesis that endodontically treated teeth are less likely to experience apical root resorption. The results revealed that endodontically treated teeth are more resistant to apical rooty resorption than vital teeth. Therefore, excess resorption observed during orthodontic movement of endodontically treated teeth may be due to unsuccessful endodontic therapy rather than the orthodontic treatment.

James E.Lupi et al (1996)[12] conducted a study to assess the frequency of root resorption and alveolar bone loss in 88 adults who had undergone orthodontic treatment. Pretreatment and posttreatment periapical radiographs were used to determine the amount of external apical root resorption and alveolar bone loss of the maxillary and mandibular incisors. They found a marked increase in the prevalence of root resorption and alveolar bone loss occurred over the course of treatment.

Baumrind S1, Korn EL, Boyd RL (1996)[13] analysed the relationship in orthodontically treated adults between upper central incisor displacement measured on lateral cephalograms and apical root resorption measured on anterior periapical x-ray films. A multiple linear regression examined incisor displacements in four directions (retraction, advancement, intrusion, and extrusion) as independent variables, attempting to account for observed differences in the dependent variable, resorption. They found that the regression coefficients for retraction were highly significant; those for extrusion, intrusion, and advancement were not.

Owman-Moll et al (1996)[14] conducted a clinical and histological study to investigate the effect on tooth movements and adverse tissue reactions (root resorption) when a fixed orthodontic appliance was activated with a controlled, continuous force of 50 cN (≈50 g) or with a four-fold larger force (200 cN ≈ 200 g). They found that the magnitude of the mean horizontal crown movement increased 50 per cent when a force of 200 cN was applied compared with a 50 cN force (3.4–5.1 mm on average) and the difference was significant and there were no significant difference in number or severity of root resorption after application of a 50 cN compared with a 200 cN force.

Harris EF1, Kineret SE, Tolley EA (1997)[16] studied a sample of full siblings (103 pairs), all of whom were treated with the same technique by one orthodontist. Crown and root lengths were measured on cephalograms and panoral films before and after treatment. Results showed significantly greater among-than within-sibship variances, meaning there is a substantive genetic factor in susceptibility to EARR.

Levander E, Malmgren O (1998)[17] conducted a study to evaluate the risk of root resorption during orthodontic treatment of patients with aplasia. The degree of root resorption was assessed before and after treatment from intra-oral radiographs of the maxillary incisors using a scale of 0-4. The results showed that there is greater degree of apical root resorption in cases of multiple aplasia (4-16 missing teeth) than in those with only one to three missing teeth. They also found that root form, treatment time with rectangular wires and intermaxillary elastics, and total treatment time were significantly related to root resorption.

Kurrol J (1998)[20] investigated the hyalinization of the periodontal ligament with time and its relationship to root surface resorption after the application of an orthodontic force, reactivated weekly, of 50 cN. He found that hyalinization was seen in all experimental groups, more often after the first 4 weeks of force application. They found that the prevalence and degree of root resorption is independent of the appliances as used in this study.

Killiany DM (1999)[21] reviewed literature on apical root shortening published in the 1990s. Data from a study that the author was involved in was used to estimate the percentage of patients who would experience different amounts of apical root shortening. It was estimated that 5% of the patients treated would experience more than 5 mm of root shortening.

McNab et al (2000)[22] investigated the association of appliance type and tooth extraction with the incidence of external apical root resorption (EARR) of posterior teeth following orthodontic treatment using Pre- and posttreatment orthopantomograms. The incidence of EARR was positively associated with tooth position ($P < .001$), appliance type ($P = .038$), and extractions ($P = .001$). They found that the incidence of EARR was 2.30 times higher for Begg appliances compared with edgewise, and it was 3.72 times higher where extractions were performed.

Glenn.T.Sameshima et al (2001)[23] conducted a study to identify pretreatment factors that will allow the clinician to predict the incidence, location, and severity of root resorption before the commencement of orthodontic treatment. They found that the resorption occurs primarily in the maxillary anterior teeth. Among maxillary anteriors, maxillary lateral incisors have shown worst resorption. Increased overjet, but not overbite, was significantly associated with greater root resorption.

Al-Qawasmi, Hartsfield JK et al (2003)[24] examined linkage and association between polymorphisms of the interleukin IL-1 (IL-1A and IL-1B) genes and EARR in 35 white American families. Buccal swab cells were collected for DNA isolation and analysis. The analysis indicates that the IL-1B polymorphism accounts for 15% of the total variation of maxillary incisor EARR. Data indicate that allele 1 at the IL-1B gene, known to decrease the production of IL-1 cytokine in vivo, significantly increases the risk of EARR and hence the IL-1B gene contributing an important predisposition to this common problem.

Yamaguchi et al (2004)[25] conducted a study to known about the relationship between external apical root resorption during orthodontic treatment and RANKL. RANKL and osteoprotegerin (OPG) production, TRAP-positive cells, and resorptive pits were determined. They found that the increase of RANKL and the decrease of OPG were greater in the severe root resorption group than in the non-resorption group. These results showed that the compressed PDL cells obtained from tissues with severe external apical root resorption may produce a large amount of RANKL and up-regulate osteoclastogenesis.

GR. Segal et al (2004)[28] conducted a Meta - analysis of available literature to elucidate possible treatment-related etiological factors such as, duration of treatment and apical displacement for external root resorption. The results have shown that mean apical root resorption was strongly correlated with total apical displacement (r = 0.822) and treatment duration (r = 0.852).

Nigel Fox et al (2005)[29] investigated treatment-related aetiological factors of EARR through meta-analytic assessment. Their results support the anecdotal evidence believed by many clinical orthodontists, that the degree of root resorption is correlated with the distance the apex of an incisor moves and the length of time of the orthodontic treatment.

Abuabara (2007)[30] searched the current knowledge of the mechanical and biological aspects of root resorption in orthodontic tooth movement. The factors relevant to root resorption can be divided into biological and mechanical factors. For mechanical factors, the extensive tooth movement, root torque and intrusive forces, movement type, orthodontic force magnitude, duration and type of force are involved. For biological factors, a genetic susceptibility, systemic disease, gender and medication intake have been demonstrated influence on root resorption.

Pizo et al (2007)[31] published a systematic review of the literature on the root resorption caused by orthodontic treatment. They found that the onset and progression of root resorption are associated with risk factors related to the orthodontic treatment and patient. Orthodontic treatment related risk factors includes duration of treatment, the magnitude of the force applied, the direction of the tooth movement, the method of force application (continuous versus intermittent), the orthodontic movement. Patient-related risk factors includes individual susceptibility on a genetic basis, some systemic diseases, anomalies in root morphology, dental trauma, and previous endodontic treatment.

Kristina Lopateine et al (2008)[32] reviewed literature to find, classify and estimate factors, that can initiate and induce root resorption during orthodontic treatment. The review shows that root resorption is significantly correlated with treatment duration, fixed appliance treatment, tooth structure, individual susceptibility, type of orthodontic tooth movement.

Yan Huang et al (2010)[53] compared root resorption level between two-step and en masse space closure procedures by using panoramic radiographs, taken before and after space closure, and measured in millimeters. They found no difference in the amount of root shortening between space closure procedures.

Janson et al (2000)[65] conducted a study to compare the amount of root resorption after orthodontic treatment between 3 different fixed orthodontic techniques. simplified standard edgewise technique (group 1), the edgewise straight wire system (group 2), and the Bioefficient Therapy (group 3). Periapical radiographs with the long cone paralleling technique were obtained for the upper and lower incisors for evaluating root resorption. The results have shown that group 3 (Bioefficient Therapy) presented less root resorption than others. They found that the factors responsible for the lesser resorption in this technique were the use of heat-activated and superelastic wires with the bracket design in this technique as well as the use of a smaller rectangular stainless steel wire (0.018 × 0.025 inch) in a 0.022 × 0.028 inch slot during incisor retraction and the finishing stages, as compared to the other techniques.

Martins D.R et al (2012)[34] evaluated the influence of intrusion mechanics combined with anterior retraction on root resorption of the maxillary incisors using pre-treatment and post-treatment periapical radiographs. The results have shown that the subjects with increased overjet and deep bite treated with combined retraction and intrusion had statistically greater root resorption ($P < 0.05$) than subjects with increased overjet and normal overbite treated with retraction alone. They have concluded that the combination of anterior retraction with intrusive mechanics causes more root resorption than anterior retraction of the maxillary incisors alone.

Ryuichi kunni (2013)[70] conducted a study to determine the interleukin (IL)-6 levels in gingival crevicular fluid (GCF) of patients with severe root resorption after orthodontic treatment and the influence of IL-6 on osteoclastic activation from human osteoclastic precursor (hOCP) cells in vitro. IL-6 levels in GCF samples collected from 20 patients with radiographic evidence of severe root resorption who had undergone orthodontic treatment were measured by ELISA. The results showed that the IL-6 levels were significantly higher in the resorption group than in the control group. They found that IL-6 may be a biomarker for root resorption. IL-6 may play an important role in inducing or facilitating orthodontically induced inflammatory root resorption.

Picanco et al (2013) [49] conducted a study to evaluate predisposing factors among patients who developed moderate or severe external root resorption (Malmgren's grades 3 and 4), on the maxillary incisors, during fixed orthodontic treatment in the permanent dentition. Periapical radiographs and lateral cephalograms were evaluated. They found that the presence of root resorption before the beginning of treatment, extractions, reduced root length, decreased crown/root ratio and thin alveolar bone represent risk factors for severe root resorption in maxillary incisors during orthodontic treatment. The results of this study demonstrates no significant relationship between root resorption and type of malocclusion, overjet, overbite and maxillomandibular relationship.

METHODS TO DETECT ROOT RESORPTION

Rygh et al (1977)[35] studied root resorption by electron microscopy. The findings showed that the elimination of hyalinized tissue leads to the removal of the cementoid and the mature collagen thus leaving a raw cemental surface without a barrier which is readily attacked by odontoclasts. Once resorption lacunae are established, the cementum is resorbed from the rear as an undermining process. He found that by continued orthodontic force application the resorption process will proceed even after all hyalinized tissue is eliminated and if the orthodontic force is discontinued or falls under a certain level, the resorption lacunae are repaired.

M.R.Harry, M.R.Sims (1982)[86] conducted a scanning electron microscopy(SEM) study of the topography of human root resorption under continuous intrusive orthodontic loadings of varying magnitude and duration. They found that loss of root length can occur within 35 days with forces as light as 50 grams. After 70 days with mean activations ranging from 50 to 200 grams, progressive apical resorption was accompanied by regions of cellular cementum repair.

Rolf Marcon Faltin, Kurt Faltin (1998)[37] conducted a study of possible root resorptions and their localization after application of continuous forces of different magnitudes using scanning electron microscopy. Twelve upper first premolars, indicated for extraction, were previously intruded with constant forces. After experimental tooth movement, the extracted teeth were dehydrated, metal-coated and examined by scanning electron microscopy. The intruded teeth showed resorptive areas consisting of lacunae (concavities) in the mineralized root surface and in the control group no resorptions were observed. Thus, their results suggest that intrusion of human teeth with continuous forces induces root resorption, depending on the magnitude of force applied.

Ahu Acar, Mustafa Koccaga (1999) [38]compared the effects on root resorption of continuous and discontinuous force application by using composite electron micrographs. One side was randomly selected to be the continuous force side, and the contralateral became the discontinuous force side. Elastics were worn 24 hours per day on the continuous force side and 12 hours per day on the discontinuous force side. The experimental procedure lasts 9 weeks. The results showed that the application of discontinuous force results in less root resorption than does the application of continuous force.

Brin et al (2003)[40] conducted a study to evaluate root resorption levels between single phase and two phase orthodontic treatment by using panoramic radiographs. Panoramic radiographs before and after fixed appliance therapy were used to evaluate root resorption. The results showed that the proportion of incisors with moderate to severe EARR was slightly greater in the 1-phase treatment group. They also found that significant associations exist among EARR, the magnitude of overjet reduction, and the time spent wearing fixed appliances.

Satu Apajalahti (2007)[39] conducted a study to compare the incidence and severity of apical root resorption in patients treated with different orthodontic appliances and to evaluate the effect of treatment duration on the degree of apical root resorption using panoramic radiographs. Active removable plates and fixed appliances were used most frequently.. Root resorption in all tooth groups, except third molars, was evaluated from pre- and post-treatment panoramic radiographs. They found that root resorption was significantly correlated with fixed appliance treatment ($P < 0.001$). The most severe resorption was seen in the maxillary incisors and premolars. They also found that with a long duration of fixed appliance treatment, the risk of severe resorption increases.

Dudic A et al (2008)[41] conducted a study to validate the use of digitized periapical radiographs in evaluating orthodontically induced apical root resorption against micro-computed tomography (micro-CT) scanning as a criterion standard test. Standardized periapical radiographs were taken before and after the experimental period. These teeth were extracted and scanned using a micro-CT technique with a 9 mum resolution. Significant differences were detected between the orthodontically moved teeth and controls: 86% of the orthodontically moved teeth and 21% of the control teeth showed apical root resorption when using micro-CT as a validation method. They found that less than half of the cases with root resorption identified using a CT scanner were identified by radiograph and hence apical root resorption may be underestimated when evaluated using digitized periapical radiographs.

Estrela , Bueno MR (2009)[42] conducted a study to evaluate a method to measure inflammatory root resorption (IRR) by using cone beam computed tomography

(CBCT) scans. IRR sites were classified according to root third and root surface. A 5-point (0-4) scoring system was used to measure the largest extension of root resorption. IRR was detected in 68.8% (83 root surfaces) of the radiographs and 100% (154 root surfaces) of the CBCT scans ($P < .001$). The extension of IRR was >1-4 mm in 95.8% of the CBCT images and in 52.1% of the images obtained by using the conventional method ($P < .001$). They found CBCT seems to be useful in the evaluation of IRR, and its diagnostic performance was better than that of periapical radiography.

Henrik Lunda et al (2012)[46] investigated the incidence and severity of root resorption during orthodontic treatment by means of cone beam computed tomography (CBCT) and also explored factors affecting orthodontically induced inflammatory root resorption (OIIRR). CBCT examinations were performed on 152 patients with Class I malocclusion. All roots from incisors to first molars were assessed on two or three occasions. They found that the upper jaw teeth and anterior teeth were significantly associated with the degree of root shortening. Practically all patients and up to 91% of all teeth showed some degree of root shortening.

Iury O. Castroa, Ana H.G. Alencarb (2013)[46] determined the frequency of apical root resorption (ARR) due to orthodontic treatment using cone beam computed tomography (CBCT) in a sample of 1256 roots from 30 patients who had Class I malocclusion with crowding. CBCT images were obtained before and after orthodontic treatment. ARR was detected using CBCT in 46% of all roots that underwent orthodontic treatment.

Estrela, Carlos et al (2014)[47] conducted a study to detect apical inflammatory root resorption (AIRR) associated with periapical lesion using cone beam computed tomography (CBCT) and scanning electronic microscopy (SEM). CBCT images were obtained from the patients with the aim of diagnosing the periapical diseases which showed complex or doubtful conditions. Two examiners assessed the presence or absence of AIRR. They found that AIRR associated with root canal infection and apical periodontitis was found in 61.4% of the cases studied by using SEM, and at least half of the cases by CBCT. The microscopic analysis remains as a reference standard against the imaging method to identify AIRR.

ROOT RESORPTION IN DIFFERENT TYPES OF MALOCCLUSION

T.Tanner et al (1999)[60] conducted a study to evaluate the apical root resorption following extraction therapy in subjects with class I and class II malocclusions and to examine the relationship between tooth movement and apical root resorption. They have selected 27 Class I and 27 Class II patients treated with edgewise mechanics following first premolar extractions and root length measurements were made on the pre- and post-treatment cephalograms. The results show that there was a mean of approximately 1 mm ($P<0.01$) of apical root shortening in Class I patients, but in Class II division I subjects the mean root resorption was more than 2 mm ($P<0.001$). They have concluded that there exist a statistically significant difference in root resorption level between class I and class II malocclusion.

Kelly chiqueto (2008)[48] conducted a study to evaluate the influence of intrusion mechanics with accentuated and reversed curve of Spee on root resorption of the maxillary and mandibular incisors. Pre treatment and post treatment periapical radiographs were used to evaluate root resorption. The results showed deep bite group treated with accentuated and reversed curve of Spee had statistically greater root resorption than the normal overbite group.

Guojian (2012)[50] conducted a cephalometic study to determine the relationship of root resorption and upper incisor compensation. The study consists of 60 patients with upper incisor compensation in skeletal II and III malocclusions and 60 patients in skeletal I malocclusion treated with fixed appliance. They were divided into four groups accroding to skeletal I(extraction),skeletal I(non-extraction), skeletal II and skeletal III malocclusion. Pre-treatment and post-treatment cephalogram measurements were taken for root resorption in all groups. They found that Upper incisor tipping of skeletal I group were normal after treatment. Root resorption of central incisor in skeletal II and III group after orthodontic treatment is significant($P< 0.01$). They also found that the variation of root resorption in skeletal II and skeletal I(extraction)group is significant($P< 0.01$).The results suggest that upper incisor compensation of skeletal II may be one of the important factors which increases root resorption.

Masahide Motokawa (2013)[51] conducted a study to clarify the prevalence and degree of root resorption induced by orthodontic treatment in patients with and without open bite.. The severity of root resorption and the root shape was assessed by using periapical radiographs. They found that there are more teeth with root resorption and abnormal root shape in open bite cases than in normal bite cases.

Long D Tieu (2014)[52] conducted a study to critically evaluate orthodontically induced external apical root resorption (OIEARR) in incisors of patients undergoing non-surgical orthodontic treatment of class II division 1 malocclusion by a systematic review of the published data. They found an increased prevalence (65.6% to 98.1%) and mild to moderate severity of OIEARR (<4 mm and <1/3 original root). There was no evidence that either the maxillary central or maxillary lateral incisor was more susceptible to OIEARR. The results have shown a weak to moderate positive correlation between treatment duration and root resorption. Current limited evidence suggests that non-surgical comprehensive orthodontic treatment to correct class II division 1 malocclusions causes increased prevalence and severity of OIEARR the more the incisor roots are displaced and the longer this movement takes.

MATERIALS AND METHODS

Eighty samples consisted of subjects with malocclusion on class I and class II skeletal base were chosen from 150 samples based on quality of radiographs. The samples for this study were chosen from the record archives of the Department of Orthodontics and Dentofacial orthopaedics, Tamilnadu Government Dental College and Hospital, Chennai based on inclusion and exclusion criteria.

Inclusion criteria:

1. Subjects with class I malocclusion on class I skeletal base.
2. Subjects with class II division 1 malocclusion on class I skeletal base.
3. Subjects with class I malocclusion on class II skeletal base.
4. Subjects with class II division 1 malocclusion on class II skeletal base.
5. Age group – 15 – 25 years.
6. Panoramic radiographs before and after treatment should be available.
7. Patient treated with premolar extractions were selected.
8. Patient treated with MBT technique were selected.
9. Patients who had completed orthodontic treatment were selected.

Exclusion criteria:

1. Patients who were treated with functional appliances.
2. Patients who had undergone orthognathic surgery.
3. Subjects treated with non-extraction were excluded.
4. Cleft lip / palate patients were excluded.
5. Teeth with periapical lesions.
6. Endodontically treated tooth.

7. Previous History of dental Trauma.
8. Cases with severe crowding in which overlap hindered visualization of roots and subsequent measurements.
9. Low quality radiographs were excluded.

Standardized Pre and Post treatment panoramic radiographs of 80 patients were analysed. Eighty cases were divided into 2 groups based on skeletal base. Cephalometric parameters were used to differentiate class I and class II skeletal base. The cephalometric parameters given in table 1 was followed.

TABLE 1 : Cephalometric parameters

Class I skeletal base	Class II skeletal base
SNA - 82 ± 2^o	SNA > 84^o
SNB – 80 ± 2^o	SNB < 78^o
ANB – 2 ± 2^o	ANB > 4^o

Group I – consisted of Malocclusion on class I skeletal base

Group II – consisted of Malocclusion on class II skeletal base

Each group is further divided into two subgroups based on molar relation.

Subgroup A – consisted of subjects with Angle's class I malocclusion

Subgroup B – consisted of subjects with Angle's class II division 1 malocclusion

Class II subdivisions were excluded. All these patients underwent fixed appliance mechanotherapy following premolar extractions.

All the panoramic radiographs used in this study had been taken in the Department of Oral medicine Diagnosis and Radiology, Tamilnadu Government

Dental College and Hospital, Chennai with the same panoramic unit ORTHOPHOS XG WITH THE PARAMETERS OF 70 Kvp, 30 mA, exposure duration of 14.0 sec and exposure dose of 47 $mGycm^2$ **(Fig 1)**and where the usual protocol of positioning the patients with back straight, erect posture and with midsagital plane perpendicular to the floor and Frankfort horizontal plane parallel to the floor was followed

Two panoramic radiographs, T1 taken at the beginning of orthodontic treatment and T2 taken after completion of orthodontic treatment were used for the study.A good visibility of maxillary and mandibular anteriors were ensured in all these panoramic radiographs.

X – Ray viewer with standard light intensity was used. A Digital vernier calliper with accuracy of 0.001 was used for measuring root length**.(Fig 2)**

METHODOLOGY

- Tooth length was measured as the distance from the tip of root apex to the midpoint of the incisal edge.(Fig 5 & 6)
- The degree of External apical root resorption (EARR) was assessed according to the index [4] proposed by Levander and Malmgren et al[17], **(fig 5)** using a 0 – 4 scale of severity, as follows :

  Score 0: Absence of changes in the root apex

  Score 1: Irregular root contour

  Score 2: EARR of less than 2 mm

  Score 3: EARR from 2 mm to one-third of original root length

  Score 4: EARR exceeding one-third of original root length

- The mean root resorption score (MRRS) for every patient at T1 and T2 were calculated for upper and lower anteriors, using the formula[5].

  Mean root resorption score = $\dfrac{\text{Sum of the scores}}{\text{Number of teeth}}$

- The individual EARR score for each tooth and the mean root resorption score for each patient was recorded and tabulated.

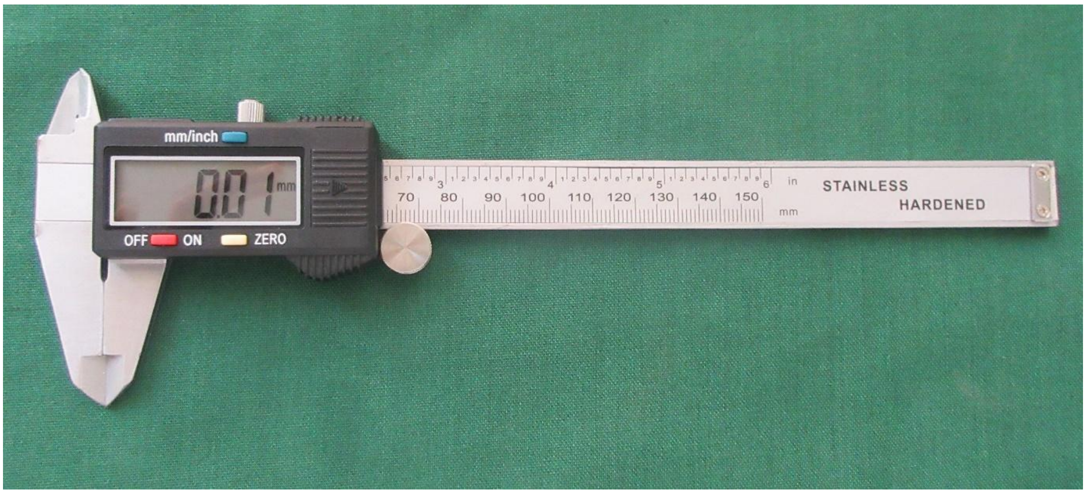
ANALYSIS OF DATA :

Statistical analysis was performed using the Statistical Package for the Social Sciences computer software (SPSS version 22.0) to analyse the data. The Normality tests Kolmogorov-Smirnov and Shapiro-Wilks test was carried out to assess the normality of variables in the study.

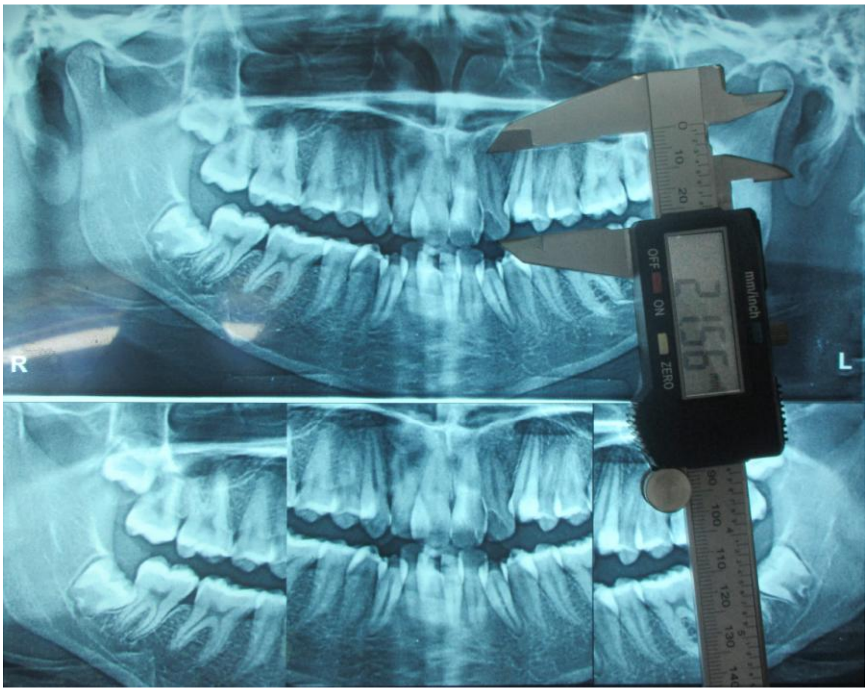
Descriptive statistics was performed for root resorption values recorded in both groups and subgroups. Mann whitney U test was used to compare root resorption levels between groups. Pearson correlation coefficient was used to correlate root resorption with different variables. Significance level was fixed as 5% ($\alpha = 0.05$).

1. ORTHOPHOS XG panoramic machine

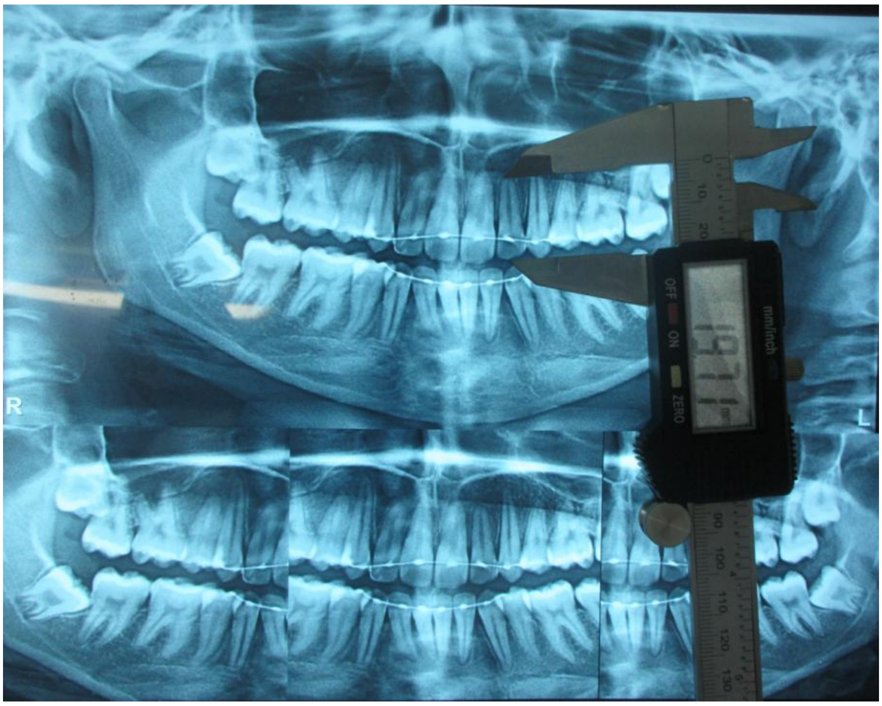
2. DIGITAL VERNIER CALIPER



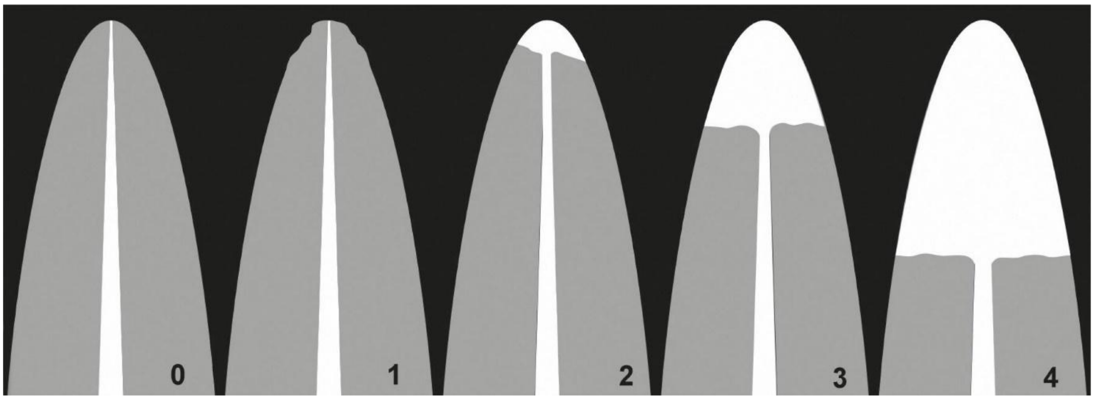
3. Pre-treatment panoramic radiograph. Tooth length measured from the tip of root apex to the mid point of incisal edge.



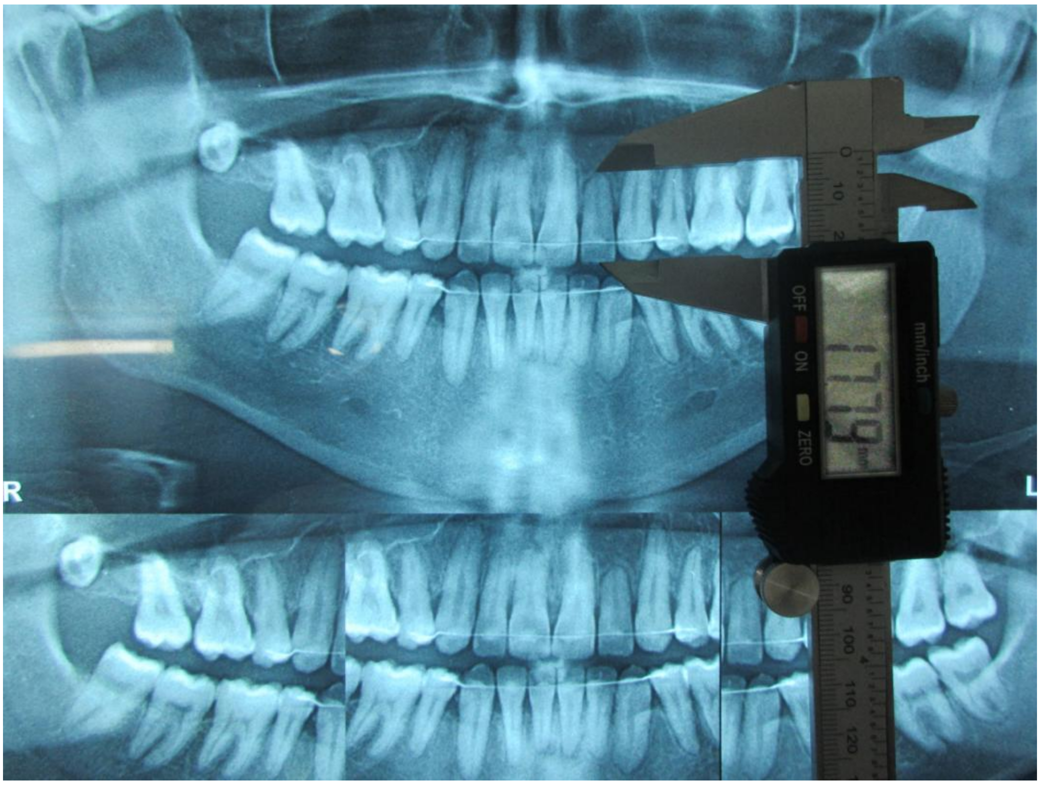
4. Post treatment panoramic radiograph. Tooth length measured from the tip of root apex to the midpoint of incisal edge.



5. Root resorption score index - levander and malmgren



6. Grade 4 root resorption score in maxillary left lateral incisor



RESULTS

The Normality tests Kolmogorov-Smirnov and Shapiro-Wilks tests results revealed that all variables did not follow Normal distribution. Therefore to analyse the data non parametric methods were applied. Mann Whitney U test was applied to compare between groups. Pearson correlation coefficient was used to correlate root resorption with various factors. SPSS version 22.0 was used to analyse the data. Significance level was fixed as 5% ($\alpha = 0.05$).

The results are discussed under five different headings.

1. Comparison of root resorption levels between class I malocclusion on class I skeletal base and class II skeletal base.
2. Comparison of root resorption levels between class II div1 malocclusion on class I skeletal base and class II skeletal base
3. Comparison of root resorption levels between class I and class II division 1 malocclusion on class I skeletal base and comparison between class I and class II div 1 malocclusion on class II skeletal base.
4. Comparison of root resorption levels between malocclusions on class I skeletal base and class II skeletal base irrespective of Angle's class I and class II division 1 malocclusion.
5. Correlation of root resorption with various factors like age, gender, overjet, overbite, treatment mechanics, treatment duration.

I. COMPARISON OF ROOT RESORPTION LEVELS BETWEEN CLASS I MALOCCLUSION ON CLASS I SKELETAL BASE AND CLASS II SKELETAL BASE

- The results have shown that there exist a statistically significant difference in root resorption levels of anterior teeth between class I malocclusion on class I and class II skeletal base.
- Root resorption levels of anterior teeth in class I malocclusion on class I skeletal base were found to be high compared to class I malocclusion on class II skeletal base.

TABLE 2 : Descriptive statistics for maxillary anteriors :

Variable		Malocclusion	
		Class I malocclusion	
		Skeletal Base	
		Class -I	Class -II
T-11	N	20	20
	Mean	1.90	.95
	Std. Dev	1.02	.94
	Median	2.00	1.00
	1st Quartile	1.50	.00
	3rd quartile	3.00	2.00
T-21	N	20	20
	Mean	1.90	1.20
	Std. Dev	1.02	1.11
	Median	2.00	1.00
	1st Quartile	1.50	.00
	3rd quartile	3.00	2.00
T-12	N	20	20
	Mean	1.65	1.05
	Std. Dev	1.23	.89

	Median	2.00	1.00
	1st Quartile	.50	.00
	3rd quartile	3.00	2.00
T-22	N	20	20
	Mean	1.70	1.15
	Std. Dev	1.17	.81
	Median	2.00	1.00
	1st Quartile	1.00	.50
	3rd quartile	3.00	2.00
T-13	N	20	20
	Mean	1.75	1.05
	Std. Dev	1.02	.89
	Median	2.00	1.00
	1st Quartile	1.00	.00
	3rd quartile	2.50	2.00
T-23	N	20	20
	Mean	1.75	1.15
	Std. Dev	1.02	.93
	Median	2.00	1.00
	1st Quartile	1.00	.00
	3rd quartile	2.50	2.00
MRRS of Maxillary Anteriors	N	20	20
	Mean	1.75	1.08
	Std. Dev	.94	.79
	Median	2.00	1.32
	1st Quartile	1.00	.33
	3rd quartile	2.60	1.75

INFERENCE : Comparison of mean values and standard deviation showed difference in root resorption levels of maxillary anteriors between class I malocclusion on class I skeletal base (1.75 ± 0.94) compared to class I malocclusion on class II skeletal base (1.08 ± 0.79) **(Table 2)**

TABLE 3 : Mann – whitney test to compare root resorption levels between class I malocclusion on class I skeletal base and class I malocclusion on class II skeletal base in relation to maxillary anteriors

Malocclusion	Variable	Skeletal Base	N	Mean Rank	Z-Value	P-Value
Class I	T-11	Class -I	20	25.48	2.801	0.005
		Class -II	20	15.53		
	T-21	Class -I	20	24.05	1.997	0.046
		Class -II	20	16.95		
	T-12	Class -I	20	23.48	1.669	0.095
		Class -II	20	17.53		
	T-22	Class -I	20	23.33	1.585	0.113
		Class -II	20	17.68		
	T-13	Class -I	20	24.43	2.208	0.027
		Class -II	20	16.58		
	T-23	Class -I	20	23.83	1.878	0.060
		Class -II	20	17.18		
	MRRS of Maxillary Anteriors	Class -I	20	24.68	2.273	0.023
		Class -II	20	16.33		

INFERENCE :

- Statistically significant differences in root resorption levels of maxillary anteriors were found between class I malocclusion on class I skeletal base and class I malocclusion on class II skeletal base.
- Maxillary right central incisor (P = 0.005), Maxillary left central incisor (P = 0.04), Maxillary right canine (P = 0.02), Maxillary anteriors of class I malocclusion on class I skeletal base (p=0.02) showed a significant increase in root resorption level compared to class I malocclusion on class II skeletal base.**(Table 3)**

TABLE 4 : Descriptive statistics for mandibular anteriors :

Variable		Malocclusion	
		Class I	
		Skeletal Base	
		Class -I	Class -II
T-31	N	20	20
	Mean	1.65	.90
	Std. Dev	.81	.64
	Median	2.00	1.00
	1st Quartile	1.00	.50
	3rd quartile	2.00	1.00
T-41	N	20	20
	Mean	1.65	.90
	Std. Dev	.81	.64
	Median	2.00	1.00
	1st Quartile	1.00	.50
	3rd quartile	2.00	1.00
T-32	N	20	20
	Mean	1.40	.75
	Std. Dev	.75	.64
	Median	2.00	1.00
	1st Quartile	1.00	.00
	3rd quartile	2.00	1.00
T-42	N	20	20
	Mean	1.40	.80
	Std. Dev	.75	.70
	Median	2.00	1.00

	1st Quartile	1.00	.00
	3rd quartile	2.00	1.00
T-33	N	20	20
	Mean	1.10	.80
	Std. Dev	1.02	.70
	Median	1.00	1.00
	1st Quartile	.00	.00
	3rd quartile	2.00	1.00
T-43	N	20	20
	Mean	1.10	.80
	Std. Dev	1.02	.70
	Median	1.00	1.00
	1st Quartile	.00	.00
	3rd quartile	2.00	1.00
MRRS of Mandibular Anteriors	N	20	20
	Mean	1.39	.84
	Std. Dev	.69	.56
	Median	1.30	1.00
	1st Quartile	1.00	.33
	3rd quartile	2.00	1.08

INFERENCE : Comparison of mean values and standard deviation showed difference in root resorption levels of mandibular anteriors between class I malocclusion on class I skeletal base and class I malocclusion on class II skeletal base **(Table 4)**

TABLE 5: Mann – whitney test to compare root resorption levels between class I malocclusion on class I skeletal base and class I malocclusion on class II skeletal base in relation to mandibular anteriors

Malocclusion	Variable	Skeletal Base	N	Mean Rank	Z-Value	P-Value
Class I	T-31	Class –I	20	25.43	2.888	0.004
		Class –II	20	15.58		
	T-41	Class –I	20	25.43	2.888	0.004
		Class –II	20	15.58		
	T-32	Class –I	20	25.23	2.735	0.006
		Class –II	20	15.78		
	T-42	Class –I	20	24.80	2.483	0.013
		Class –II	20	16.20		
	T-33	Class –I	20	21.95	.834	0.405
		Class –II	20	19.05		
	T-43	Class –I	20	21.95	.834	0.405
		Class –II	20	19.05		
	MRRS of Mandibular Anteriors	Class –I	20	24.78	2.372	0.018
		Class –II	20	16.23		

<u>INFERENCE :</u>

- Statistically significant differences were found in root resorption levels of mandibular anteriors between class I malocclusion on class I skeletal base and class II skeletal base. **(Table 5)**
- Mandibular central incisors (P = 0.004), Mandibular left lateral incisor (P = 0.006), Mandibular right lateral incisor (P =0.01), overall mandibular anterior teeth (P = 0.01) 0f class I malocclusion on class I skeletal base showed a significant increase in root resorption levels compared to class I malocclusion on class II skeletal base.

TABLE 6: Mann – whitney test to compare root resorption levels between class I malocclusion on class I skeletal base and class II skeletal base in relation to overall anterior teeth.

Malocclusion	Variable	Skeletal Base	N	Mean	S.D	Z-Value	P-Value
Class I	MRRS of Individual Patient	Class –I	20	1.57	0.77	2.386	0.017
		Class -II	20	0.96	0.60		

INFERENCE :

- Statistically significant differences were found in root resorption levels of anterior teeth between class I malocclusion on class I and class II skeletal base (P = 0.01) **(Table 6)**
- Mean root resorption value of anterior teeth was 1.57 mm for class I malocclusion on class I skeletal base and 0.96 mm for class I malocclusion on class II skeletal base.
- There was a statistically significant increase in root resorption levels of anterior teeth on class I malocclusion on class I skeletal base compared to class I malocclusion on class II skeletal base.

II. COMPARISON OF ROOT RESORPTION LEVELS BETWEEN CLASS II DIV 1 MALOCCLUSION ON CLASS I SKELETAL BASE AND CLASS II SKELETAL BASE

- No statistically significant differences were found between root resorption levels of anterior teeth in class II div 1 malocclusion on class I and class II skeletal base.

TABLE 7 : Descriptive statistics for maxillary anteriors :

Variable		Malocclusion	
		Class II Div-1 malocclusion	
		Skeletal Base	
		Class -I	Class -II
T-11	N	20	20
	Mean	1.65	1.60
	Std. Dev	.75	1.14
	Median	2.00	2.00
	1st Quartile	1.00	.50
	3rd quartile	2.00	2.50
T-21	N	20	20
	Mean	1.65	1.70
	Std. Dev	.75	1.03
	Median	2.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.50
T-12	N	20	20
	Mean	1.95	2.05
	Std. Dev	1.00	1.10
	Median	2.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	3.00	3.00
T-22	N	20	20
	Mean	2.00	2.16
	Std. Dev	.92	.96
	Median	2.00	2.00

	1st Quartile	1.00	1.00
	3rd quartile	3.00	3.00
T-13	N	20	20
	Mean	1.45	1.85
	Std. Dev	1.00	.99
	Median	1.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-23	N	20	20
	Mean	1.50	1.85
	Std. Dev	.95	.99
	Median	1.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
MRRS of Maxillary Anteriors	N	20	20
	Mean	1.70	1.84
	Std. Dev	.68	.92
	Median	1.66	2.00
	1st Quartile	1.00	1.16
	3rd quartile	2.17	2.45

INFERENCE : Comparison of mean values and standard deviation showed difference in root resorption levels of maxillary anteriors between class II div 1 malocclusion on class I and class II skeletal base. **(Table 7)**

TABLE 8 : Mann – whitney test to compare root resorption levels between class II div 1 malocclusion on class I skeletal base and class II div 1 malocclusion on class II skeletal base in relation to maxillary anteriors

Malocclusion	Variable	Skeletal Base	N	Mean Rank	Z-Value	P-Value
Class II Div-1	T-11	Class -I	20	20.40	.057	0.955
		Class -II	20	20.60		
	T-21	Class -I	20	20.00	.287	0.774
		Class -II	20	21.00		
	T-12	Class -I	20	19.95	.312	0.755
		Class -II	20	21.05		
	T-22	Class -I	20	19.20	.478	0.633
		Class -II	19	20.84		
	T-13	Class -I	20	18.15	1.328	0.184
		Class -II	20	22.85		
	T-23	Class -I	20	18.30	1.249	0.212
		Class -II	20	22.70		
	MRRS of Maxillary Anteriors	Class -I	20	19.58	.506	0.613
		Class -II	20	21.43		

INFERENCE : No statistically significant differences were found in root resorption levels of maxillary anteriors between class II div 1 malocclusion on class I and class II skeletal base. **(Table 8)**

TABLE 9 : Descriptive statistics for mandibular anteriors :

Variable		Malocclusion	
		Class II Div-1 malocclusion	
		Skeletal Base	
		Class -I	Class –II
T-31	N	20	20
	Mean	1.40	1.85
	Std. Dev	.75	.67
	Median	2.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-41	N	20	20
	Mean	1.40	1.80
	Std. Dev	.75	.62
	Median	2.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-32	N	20	20
	Mean	1.25	1.75
	Std. Dev	.79	.55
	Median	1.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-42	N	20	20
	Mean	1.25	1.80
	Std. Dev	.79	.62
	Median	1.00	2.00

	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-33	N	20	20
	Mean	1.15	1.55
	Std. Dev	.93	1.00
	Median	1.00	1.50
	1st Quartile	1.00	1.00
	3rd quartile	1.00	2.00
T-43	N	20	20
	Mean	1.15	1.55
	Std. Dev	.93	1.00
	Median	1.00	1.50
	1st Quartile	1.00	1.00
	3rd quartile	1.00	2.00
MRRS of Mandibular Anteriors	N	20	20
	Mean	1.26	1.69
	Std. Dev	.69	.51
	Median	1.17	1.66
	1st Quartile	.83	1.33
	3rd quartile	1.66	2.15

INFERENCE : Comparison of mean values and standard deviation showed difference in root resorption levels of mandibular anteriors between class II div 1 malocclusion on class I and class II skeletal base.**(Table 9)**

TABLE 10 : Mann – whitney U test to compare root resorption levels between class II div 1 malocclusion on class I skeletal base and class II skeletal base in relation to mandibular anteriors

Malocclusion	Variable	Skeletal Base	N	Mean Rank	Z-Value	P-Value
Class II Div-1	T-31	Class -I	20	17.73	1.672	0.095
		Class -II	20	23.28		
	T-41	Class -I	20	18.00	1.529	0.126
		Class -II	20	23.00		
	T-32	Class –I	20	17.18	2.013	0.044
		Class –II	20	23.83		
	T-42	Class –I	20	16.95	2.120	0.034
		Class –II	20	24.05		
	T-33	Class –I	20	18.05	1.415	0.157
		Class –II	20	22.95		
	T-43	Class –I	20	18.05	1.415	0.157
		Class –II	20	22.95		
	MRRS of Mandibular Anteriors	Class –I	20	17.18	1.816	0.069
		Class –II	20	23.83		

INFERENCE :

- No statistically significant differences were found in root resorption levels of mandibular anteriors between class II div 1 malocclusion on class I and class II skeletal base except for mandibular lateral incisors. **(Table 10)**
- Mandibular left lateral incisor (P = 0.04) and Mandibular right lateral incisor (P = 0.03) of class II div 1 malocclusion on class II skeletal base showed significant increase in root resorption level compared to class I skeletal base.

TABLE 11 : Mann – whitney U test to compare root resorption levels between class II div 1 malocclusion on class I skeletal base and class II skeletal base in relation to overall anterior teeth

Malocclusion	Variable	Skeletal Base	N	Mean	S.D	Z-Value	P-Value
Class II div 1 malocclusion	MRRS of Individual Patient	Class -I	20	1.48	0.60	1.100	0.271
		Class -II	20	1.78	0.67		

<u>INFERENCE</u> : No statistically significant difference were found in root resorption levels of anterior teeth between class II div 1 malocclusion on class I and class II skeletal base. **(Table 11)**

III. COMPARISON OF ROOT RESORPTION LEVELS BETWEEN CLASS I AND CLASS II DIV 1 MALOCCLUSION ON CLASS I SKELETAL BASE AND COMPARISION OF CLASS I AND CLASS ii DIV 1 MALOCCLUSION ON CLASS II SKELETAL BASE

- The results have shown a statistically significant difference in root resorption levels between class I and class II div 1 malocclusion on class II skeletal base.
- There is a significant increase in root resorption levels of overall anterior teeth in class II div 1 malocclusion on class II skeletal base compared to class I malocclusion on class II skeletal base.
- No statistically significant differences were found between root resorption levels of class I and class II div 1 malocclusion on class I skeletal base.

TABLE 12 : Descriptive statistics for maxillary anteriors :

Variable		Skeletal Base			
		Class –I Malocclusion		Class –II Malocclusion	
		Class I	Class II Div-1	Class I	Class II Div-1
T-11	N	20	20	20	20
	Mean	1.90	1.65	.95	1.60
	Std. Dev	1.02	.75	.94	1.14
	Median	2.00	2.00	1.00	2.00
	1st Quartile	1.50	1.00	.00	.50
	3rd quartile	3.00	2.00	2.00	2.50
T-21	N	20	20	20	20
	Mean	1.90	1.65	1.20	1.70
	Std. Dev	1.02	.75	1.11	1.03
	Median	2.00	2.00	1.00	2.00
	1st Quartile	1.50	1.00	.00	1.00
	3rd quartile	3.00	2.00	2.00	2.50
T-12	N	20	20	20	20
	Mean	1.65	1.95	1.05	2.05
	Std. Dev	1.23	1.00	.89	1.10
	Median	2.00	2.00	1.00	2.00
	1st Quartile	.50	1.00	.00	1.00
	3rd quartile	3.00	3.00	2.00	3.00
T-22	N	20	20	20	20
	Mean	1.70	2.00	1.15	2.16

	Std. Dev	1.17	.92	.81	.96
	Median	2.00	2.00	1.00	2.00
	1st Quartile	1.00	1.00	.50	1.00
	3rd quartile	3.00	3.00	2.00	3.00
T-13	N	20	20	20	20
	Mean	1.75	1.45	1.05	1.85
	Std. Dev	1.02	1.00	.89	.99
	Median	2.00	1.00	1.00	2.00
	1st Quartile	1.00	1.00	.00	1.00
	3rd quartile	2.50	2.00	2.00	2.00
T-23	N	20	20	20	20
	Mean	1.75	1.50	1.15	1.85
	Std. Dev	1.02	.95	.93	.99
	Median	2.00	1.00	1.00	2.00
	1st Quartile	1.00	1.00	.00	1.00
	3rd quartile	2.50	2.00	2.00	2.00
MRRS of Maxillary Anteriors	N	20	20	20	20
	Mean	1.75	1.70	1.08	1.84
	Std. Dev	.94	.68	.79	.92
	Median	2.00	1.66	1.32	2.00
	1st Quartile	1.00	1.00	.33	1.16
	3rd quartile	2.60	2.17	1.75	2.45

INFERENCE : Comparison of mean values and standard deviation showed a difference in root resorption levels of maxillary anteriors between class I and class II division 1 malocclusion on both class I and class II skeletal base.**(Table 12)**

TABLE 13 : MANN – WHITNEY U TEST TO COMPARE ROOT RESORPTION LEVELs.

Skeletal Base	Variable	Malocclusion	N	Mean Rank	Z-Value	P-Value
Class –I	T-11	Class I	20	22.58	1.201	0.230
		Class II Div-1	20	18.43		
	T-21	Class I	20	22.58	1.201	0.230
		Class II Div-1	20	18.43		
	T-12	Class I	20	19.13	0.777	0.437
		Class II Div-1	20	21.88		
	T-22	Class I	20	19.10	0.796	0.426
		Class II Div-1	20	21.90		
	T-13	Class I	20	22.33	1.027	0.304
		Class II Div-1	20	18.68		
	T-23	Class I	20	22.15	0.932	0.351
		Class II Div-1	20	18.85		
	MRRS of Maxillary Anteriors	Class I	20	21.30	0.436	0.663
		Class II Div-1	20	19.70		
Class –II	T-11	Class I	20	17.20	1.857	0.063
		Class II Div-1	20	23.80		
	T-21	Class I	20	17.90	1.455	0.146
		Class II Div-1	20	23.10		
	T-12	Class I	20	15.45	2.834	0.005
		Class II Div-1	20	25.55		
	T-22	Class I	20	14.95	2.961	0.003
		Class II Div-1	19	25.32		
	T-13	Class I	20	16.03	2.535	0.011
		Class II Div-1	20	24.98		
	T-23	Class I	20	16.73	2.154	0.031
		Class II Div-1	20	24.28		
	MRRS of Maxillary Anteriors	Class I	20	15.55	2.696	0.007

INFERENCE :

- No statistically significant differences were found in root resorption levels of maxillary anteriors between class I malocclusion and class II division 1 malocclusion on class I skeletal base.
- Statistically significant differences were found in root resorption levels of maxillary anteriors between class I malocclusion and class II division 1 malocclusion on class II skeletal base. Maxillary right lateral incisor ($p = 0.005$), maxillary left lateral incisor ($P=0.003$), maxillary right canine ($p = 0.011$), maxillary left canine ($p=0.03$) and overall score of maxillary anteriors ($p = 0.007$) of class II div 1 malocclusion on class II skeletal base showed increased root rtesorption levels than class I malocclusion on class II skeletal base. **(Table 13)**

TABLE 14 : Descriptive statistics for mandibular anteriors :

Variable		Skeletal Base			
		Class –I Malocclusion		Class –II Malocclusion	
		Class I	Class II Div-1	Class I	Class II Div-1
T-31	N	20	20	20	20
	Mean	1.65	1.40	.90	1.85
	Std. Dev	.81	.75	.64	.67
	Median	2.00	2.00	1.00	2.00
	1st Quartile	1.00	1.00	.50	1.00
	3rd quartile	2.00	2.00	1.00	2.00
T-41	N	20	20	20	20
	Mean	1.65	1.40	.90	1.80
	Std. Dev	.81	.75	.64	.62
	Median	2.00	2.00	1.00	2.00
	1st Quartile	1.00	1.00	.50	1.00
	3rd quartile	2.00	2.00	1.00	2.00

T-32	N	20	20	20	20
	Mean	1.40	1.25	.75	1.75
	Std. Dev	.75	.79	.64	.55
	Median	2.00	1.00	1.00	2.00
	1st Quartile	1.00	1.00	.00	1.00
	3rd quartile	2.00	2.00	1.00	2.00
T-42	N	20	20	20	20
	Mean	1.40	1.25	.80	1.80
	Std. Dev	.75	.79	.70	.62
	Median	2.00	1.00	1.00	2.00
	1st Quartile	1.00	1.00	.00	1.00
	3rd quartile	2.00	2.00	1.00	2.00
T-33	N	20	20	20	20
	Mean	1.10	1.15	.80	1.55
	Std. Dev	1.02	.93	.70	1.00
	Median	1.00	1.00	1.00	1.50
	1st Quartile	.00	1.00	.00	1.00
	3rd quartile	2.00	1.00	1.00	2.00
T-43	N	20	20	20	20
	Mean	1.10	1.15	.80	1.55
	Std. Dev	1.02	.93	.70	1.00
	Median	1.00	1.00	1.00	1.50
	1st Quartile	.00	1.00	.00	1.00
	3rd quartile	2.00	1.00	1.00	2.00
MRRS of Mandibular Anteriors	N	20	20	20	20
	Mean	1.39	1.26	.84	1.69
	Std. Dev	.69	.69	.56	.51
	Median	1.30	1.17	1.00	1.66
	1st Quartile	1.00	.83	.33	1.33
	3rd quartile	2.00	1.66	1.08	2.15

INFERENCE : Comparison of mean values and standard deviation of root resorption levels of mandibular anteriors showed difference between class II div 1 malocclusion on class II skeletal base (1.69 ± 0.51) than class I malocclusion on class II skeletal base (0.84 ±0.56). **(Table 14)**

TABLE 15 : MANN – WHITNEY U TEST TO COMPARE ROOT RESORPTION LEVELS

Skeletal Base	Variable	Malocclusion	N	Mean Rank	Z-Value	P-Value
Class –I	T-31	Class I	20	21.78	0.749	0.454
		Class II Div-1	20	19.23		
	T-41	Class I	20	21.78	0.749	0.454
		Class II Div-1	20	19.23		
	T-32	Class I	20	21.58	0.636	0.525
		Class II Div-1	20	19.43		
	T-42	Class I	20	21.58	0.636	0.525
		Class II Div-1	20	19.43		
	T-33	Class I	20	20.18	0.187	0.852
		Class II Div-1	20	20.83		
	T-43	Class I	20	20.18	0.187	0.852
		Class II Div-1	20	20.83		
	MRRS of Mandibular Anteriors	Class I	20	21.20	0.385	0.700
		Class II Div-1	20	19.80		
Class –II	T-31	Class I	20	14.03	3.768	<0.001
		Class II Div-1	20	26.98		
	T-41	Class I	20	14.10	3.745	<0.001
		Class II Div-1	20	26.90		
	T-32	Class I	20	13.40	4.128	<0.001
		Class II Div-1	20	27.60		
	T-42	Class I	20	13.80	3.868	<0.001
		Class II Div-1	20	27.20		
	T-33	Class I	20	16.23	2.444	0.015
		Class II Div-1	20	24.78		
	T-43	Class I	20	16.23	2.444	0.015
		Class II Div-1	20	24.78		
	MRRS of Mandibular Anteriors	Class I	20	12.90	4.153	<0.001
		Class II Div-1	20	28.10		

INFERENCE :

- No statistically significant difference in root resorption levels of mandibular anteriors were found between class I and class II div 1 malocclusion on class I skeletal base. **(Table 15)**
- Statistically significant differences were found in root resorption levels of mandibular anteriors between class I and class II div 1 malocclusion on class II skeletal base.
- Mandibular incisors ($p < 0.001$), mandibular canines ($p = 0.015$) and overall mandibular anteriors ($p < 0.001$) of class II division 1 malocclusion on class II skeletal base showed significant increase in root resorption rate compared to class I malocclusion on class II skeletal base.

TABLE 16 : Mann – whitney U test to compare root resorption levels between class I and class II div 1 malocclusion on each skeletal base.

Skeletal Base	Variable	Malocclusion	N	Mean	S.D	Z-Value	P-Value
Class I	MRRS of Individual Patient	Class I	20	1.57	0.77	0.339	0.734
		Class II Div-1	20	1.48	0.60		
Class II	MRRS of Individual Patient	Class I	20	0.96	0.60	3.281	0.001
		Class II Div-1	20	1.78	0.67		

INFERENCE :

- No statistically significant differences were found in root resorption levels of overall anterior teeth between class I malocclusion and class II div 1 malocclusion on class I skeletal base. **(Table 16)**
- Statistically significant differences were found in root resorption levels of overall anterior teeth between class I malocclusion and class II div 1 malocclusion on class II skeletal base ($p = 0.001$).

IV) COMPARISON OF ROOT RESORPTION LEVELS BETWEEN MALOCCLUSIONS ON CLASS I AND CLASS II SKELETAL BASE IRRESPECTIVE OF ANGLE'S MALOCCLUSION

- No statistically significant difference were found in root resorption levels of anterior teeth between malocclusions on class I and class II skeletal base.

TABLE 17 : DESCRIPTIVE STATISTICS FOR MAXILLARY ANTERIORS

Variable	Statistic	Skeletal Base	
		Class –I	**Class –II**
T-11	N	40	40
	Mean	1.77	1.27
	Std. Dev	.89	1.09
	Median	2.00	1.00
	1st Quartile	1.00	.00
	3rd quartile	2.00	2.00
T-21	N	40	40
	Mean	1.77	1.45
	Std. Dev	.89	1.08
	Median	2.00	1.50
	1st Quartile	1.00	.50
	3rd quartile	2.00	2.00
T-12	N	40	40
	Mean	1.80	1.55
	Std. Dev	1.11	1.11
	Median	2.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	3.00	2.00

T-22	N	40	40
	Mean	1.85	1.64
	Std. Dev	1.05	1.01
	Median	2.00	2.00
	1st Quartile	1.00	1.00
	3rd quartile	3.00	2.00
T-13	N	40	40
	Mean	1.60	1.45
	Std. Dev	1.01	1.01
	Median	2.00	1.50
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-23	N	40	40
	Mean	1.62	1.50
	Std. Dev	.98	1.01
	Median	2.00	2.00
	1st Quartile	1.00	1.00
MRRS of Maxillary Anteriors	N	40	40
	Mean	1.73	1.46
	Std. Dev	.81	.93
	Median	1.66	1.66
	1st Quartile	1.00	.66
	3rd quartile	2.33	2.00

INFERENCE : Comparison of mean values and standard deviations of root resorption levels showed difference in root resorption levels between class I skeletal base (1.73 ± 0.81) and class II skeletal base (1.46 ± 0.93) **(Table 17)**

TABLE 18: Mann – whitney u test to compare root resorption levels between classI and class II skeletal base in relation to Maxillary anteriors

Variable	Skeletal Base	N	Mean Rank	Z-Value	P-Value
T-11	Class –I	40	45.79	2.127	0.033
	Class –II	40	35.21		
T-21	Class –I	40	43.93	1.378	0.168
	Class –II	40	37.08		
T-12	Class –I	40	43.20	1.074	0.283
	Class –II	40	37.80		
T-22	Class –I	40	42.33	0.949	0.342
	Class –II	39	37.62		
T-13	Class –I	40	42.23	0.692	0.489
	Class –II	40	38.78		
T-23	Class –I	40	41.83	0.533	0.594
	Class –II	40	39.18		
MRRS of Maxillary Anteriors	Class –I	40	44.09	1.388	0.165
	Class –II	40	36.91		

INFERENCE: No statistically significant differences were found in comparision of root resorption levels of maxillary anteriors between class I and class II skeletal base except for maxillary right central incisor. Root resorption levels of maxillary right central incisor shows a statistically significant difference between class I and class II skeletal base (P = 0.03). **(Table 18)**

TABLE 19: DESCRIPTIVE STATISTICS FOR MANDIBULAR ANTERIORS

Variable	Statistic	Skeletal Base	
		Class –I	**Class –II**
T-31	N	40	40
	Mean	1.53	1.38
	Std. Dev	.78	.81
	Median	2.00	1.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-41	N	40	40
	Mean	1.53	1.35
	Std. Dev	.78	.77
	Median	2.00	1.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-32	N	40	40
	Mean	1.33	1.25
	Std. Dev	.76	.78
	Median	1.50	1.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-42	N	40	40
	Mean	1.33	1.30
	Std. Dev	.76	.82

	Median	1.50	1.00
	1st Quartile	1.00	1.00
	3rd quartile	2.00	2.00
T-33	N	40	40
	Mean	1.13	1.18
	Std. Dev	.97	.93
	Median	1.00	1.00
	1st Quartile	.00	.50
	3rd quartile	2.00	2.00
T-43	N	40	40
	Mean	1.13	1.18
	Std. Dev	.97	.93
	Median	1.00	1.00
	1st Quartile	.00	.50
	3rd quartile	2.00	2.00
MRRS of Mandibular Anteriors	N	40	40
	Mean	1.33	1.27
	Std. Dev	.69	.68
	Median	1.17	1.33
	1st Quartile	1.00	1.00
	3rd quartile	1.92	1.66

INFERENCE : Comparision of mean and standard deviations of mandibular anteriors showed difference in root resorption rate between class I skeletal base (1.33 ± 0.69) and class II skeletal base (1.27 ± 0.68). **(Table 19)**

TABLE 20 : Mann – whitney U test to compare root resorption levels between class I and class II skeletal base in relation to mandibular anteriors

Variable	Skeletal Base	N	Mean Rank	Z-Value	P-Value
T-31	Class –I	40	42.79	0.947	0.344
	Class –II	40	38.21		
T-41	Class –I	40	43.06	1.065	0.287
	Class –II	40	37.94		
T-32	Class –I	40	41.90	0.582	0.561
	Class –II	40	39.10		
T-42	Class –I	40	41.24	0.305	0.760
	Class –II	40	39.76		
T-33	Class –I	40	39.68	0.337	0.736
	Class –II	40	41.33		
T-43	Class –I	40	39.68	0.337	0.736
	Class –II	40	41.33		
MRRS of Mandibular Anteriors	Class –I	40	41.41	0.355	0.722
	Class –II	40	39.59		

INFERENCE : No statistically significant differences were found in comparision of root resorption levels of mandibular anteriors between class I and class II skeletal base. **(Table 20)**

TABLE 21 : MANN – WHITNEY U TEST TO COMPARE ROOT RESORPTION LEVELS BETWEEN CLASS I AND CLASS II SKELETAL BASE IN RELATION TO OVERALL ANTERIOR TEETH

Variable	Skeletal Base	N	Mean	S.D	Mean Rank	Z-Value	P-Value
MRRS of Individual Patient	Class –I	40	1.52	0.68	43.69	1.230	0.219
	Class –II	40	1.37	0.75	37.31		

INFERENCE : No statistically significant differences were found in comparision of root resorption levels of anterior teeth between class I and class II skeletal base. **(Table 21)**

V) CORRELATION OF ROOT RESORPTION WITH VARIOUS FACTORS

TABLE 22 : PEARSON CORRELATIONS COEFFICIENTS :

		MRRS of Maxillary Anteriors	**MRRS of Mandibular Anteriors**	**MRRS of overall anterior teeth**
Age (years)	Correlation	.191	.170	.203
	P-Value	.089	.131	.071
	N	80	80	80
Overjet (mm)	Correlation	.252	.229	.263
	P-Value	.024	.041	.019
	N	80	80	80
Overbite (mm)	Correlation	.343	.287	.348
	P-Value	.002	.010	.002
	N	80	80	80
Treatment Duration (months)	Correlation	.319	.343	.357
	P-Value	.004	.002	.001
	N	80	80	80

INFERENCE :

- No statistically significant correlation was found between age and root resorption of anterior teeth. **(Table 22)**
- Statistically significant correlation exist between overjet and root resorption of maxillary anteriors (p = 0.02), mandibular anteriors (P = 0.04) and overall anterior teeth (P = 0.01)
- Statistically significant correlation exist between overbite and root resorption of maxillary anteriors (P = 0.002), mandibular anteriors (P = 0.01) and overall anterior teeth (P = 0.002)
- Statistically significant correlation exist between treatment duration and root resorption of maxillary anteriors (P = 0.004), mandibular anteriors (P = 0.002) and overall anterior teeth (P =0.001).

TABLE 23 : Mann whitney test to compare root resorption levels between genders

Variable	Gender	N	Mean	S.D	Z-Value	P-Value
MRRS of Maxillary Anteriors	Male	39	1.79	0.87	1.872	0.061
	Female	41	1.40	0.85		
MRRS of Mandibular Anteriors	Male	39	1.33	0.69	0.414	0.679
	Female	41	1.28	0.68		
MRRS of Individual Patient	Male	39	1.56	0.72	1.578	0.115
	Female	41	1.34	0.71		

INFERENCE : No statistically significant correlation were found between gender and root resorption of anterior teeth. **(Table 23)**

TABLE 24 :Mann – whitney test to compare root resorption values between treatment mechanics

Variable	Treatment Mechanics	N	Mean	S.D	Z-Value	P-Value
MRRS of Maxillary Anteriors	Retraction	47	1.26	0.86	4.190	<0.001
	Retraction and Intrusion	33	2.06	0.67		
MRRS of Mandibular Anteriors	Retraction	47	1.11	0.63	3.007	0.003
	Retraction and Intrusion	33	1.56	0.66		
MRRS of Individual Patient	Retraction	47	1.19	0.67	3.890	<0.001
	Retraction and Intrusion	33	1.82	0.61		

INFERENCE :

- Statistically significant correlation exist between root resorption levels of maxillary anteriors($P<0.001$), mandibular anteriors (P = o.003) and overall anterior teeth ($P < 0.001$) and treatment mechanics. **(Table 24)**

Results :

1. Statistically significant increase ($P = 0.01$) in root resorption levels of anterior teeth was found in non compensated class I malocclusion compared to compensated class I malocclusion.
2. No statistically significant difference in root resorption levels of anterior teeth was found between compensated and non compensated class II division 1 malocclusion.
3. No statistically significant difference in root resorption levels of anterior teeth was found between Angle,s class I and class II division 1 malocclusion on class I skeletal base.
4. Statistically significant ($P = 0.001$) increase in root resorption levels of anterior teeth was found in Angle's class II division 1 malocclusion on class II skeleatal base compared to Angle,s class I malocclusion on class II skeletal base.
5. Age and Gender has no statistically significant correlation with root resorption.
6. Overjet ($P = 0.01$) and overbite ($P = 0.002$)has statistically significant correlation with post treatment root resorption.
7. Treatment duration had a statistically significant correlation ($P = 0.001$) with post treatment root resorption; the longer the duration, the more severe the root resorption.

8. Treatment mechanics had a statistically significant correlation with post treatment root resorption. It was found that increased amount of root resorption occurs when intrusion mechanics were associated with retraction mechanics.

DISCUSSION

Orthodontically induced inflammatory root resorption is one of the most important complication of orthodontic treatment. This root resorption differs from other kinds of resorption. This is a sterile, local inflammatory process, which is complicated and has all characteristic inflammatory symptoms. Root resorption induces root shortening and weakening of teeth.[1,2,5,9] Root resorption is considered as clinically important when 1-2 mm of the root length is lost [17]. Severe root resorption during orthodontic treatment (>5mm) occurs very rarely just in 1-5 % of patients.

There are three degrees of severity of root resorption. A) Cementum or surface resorption where only outer cementum layer is resorbed. B) Dentin resorption where cementum and outer dentin layer are resorbed. C) Surrounding root resorption, where hard apical tissues fully resorbs and apical tissues under cementum are lost and do not regenerate.

The mechanism of root resorption is not completely explored. According to Brudvik and Rygh, inflammatory root resorption induced by orthodontic treatment is a part of process of elimination of hyaline zone.[20] It is considered that occurrence of root resorption can be induced by the strong force through orthodontic treatment and hyalinization of periodontal ligament induced by increased activity of cementoclasts, osteoclasts. During tooth movement, areas of compression, where osteoclasts are inducing bone resorption and areas of tension where osteoblasts are inducing bone deposition are formed. Thus a tooth moves towards the side of bone resorption. Any imbalance between bone resorption and deposition results in loss of protective characteristic of cementum which may contribute to the cementoclastic osteoclastic activity, resorbing areas of the root. Tooth root surface under the hyaline zone resorbs.[20,27] It is possible that a force occurring during orthodontic treatment may directly damage outer root surface.[14,15]

Various factors can initiate and induce root resorption during orthodontic treatment.[1,2,3,4,6,18] These factors can be divided into biological and mechanical factors. Biological factors includes Genetics, systemic factors, nutrition, chronological age, dental age, ethnic group, habits, anomalies of position and number of teeth, dental trauma, endodontically treated teeth and malocclusion. Mechanical factors includes orthodontic appliances, tooth extraction, type of orthodontic tooth movement, orthodontic force and treatment duration.

Numerous studies have been carried out to find out various patient related and treatment related risk factors associated with orthodontically induced external apical root resorption.[8,9 ,21,25,38,41] But only few investigators have focussed their interest on the relationship between malocclusion and root resorption.[32,38,39] The present study aimed to compare the root resorption levels between class I, class II division 1 malocclusion on class I and class II skeletal base.

Skeletal malocclusion have dentoalveolar compensation.[48,50,54,68] Studies have shown that in cases of skeletal malocclusion, buccolingual position and inclination of incisors, inclination of occlusal plane and narrowing of alveolar process with close proximity of roots to alveolar process occurs, which in turn increases the risk of root resorption. These changes differs from non compensated dentoalveolar malocclusion.

During facial growth and development, normal occlusion can be attained and maintained despite some variation in facial pattern, primarily as a result of dental compensation.[48,54] For existing sagittal jaw discrepancies, compensatory inclination of the maxillary and mandibular incisors results in normal incisal relationships. The cant of occlusal plane also acts to adjust sagittal relationships between the maxillary and mandibular dental arches.[56,57] The clinical significance of the present study lies in addressing the patients with high risk of root resorption during orthodontic treatment.

The clinical diagnosis of root resorption is based mainly on routine radiographic procedures, such as periapical radiography, panoramic radiography, CBCT and CT scans. Periapical radiographs are widely used in dentistry, but however limited in their coverage of the maxillomandibular structures and multiple films are needed for a comprehensive examination.[40] Periapical films have a magnification factor of less than 5 %.

Conventional extra oral radiographs such as the lateral cephalogram can achieve better coverage, but anatomical structures of the facial skeleton that are not in the midline cannot be measured accurately because of distortion. Bilateral structures produce two images and it is difficult to differentiate between right and left sides.[39]

Panoramic radiograph is another commonly used radiograph that has overcome many limitations of extraoral radiography including controlled magnification in the vertical dimension, decreased overlapping of tooth contact areas and single point contact of the rotating beam onto the object to allow for a sharper, well defined image.[39,44]

CT scans and CBCT provides more accurate three dimensional images of teeth.[46,47,59] Dudic et al found that compared with CBCT, panoramic radiographs underestimate apical root resorption as a result of orthodontic tooth movement. However it has got limitations compared to conventional radiographs, which includes increased cost and amount of radiation. The effective dose of CBCT may be 1.5 to 3.3 times higher than that associated with panoramic radiographs.

The present study have chosen panoramic radiography for measuring root resorption because of three main reasons. They are A) A panoramic film is routinely ordered as the primary pre treatment and post treatment radiograph. B) The advantage of panoramic film are less radiation exposure, less chairside time, less operator time and better patient co – operation. C) Panoramic radiographs has the added advantage of displaying entire maxillomandibular region on single film. It provides increased coverage of the dental arches and associated structures, relatively undistorted anatomic images, reduced radiation dosage for the patient and simplicity of operation.

However, there are known limitations of panoramic radiography. The quality of image is dependent on correct patient positioning and closeness of the desired anatomical structures to the focal trough.

In this study, apical dental alterations were classified according to the widely applicable and accepted index proposed by Malmgren et al and modified by Levander et al.[17] This method is predominantly used in root resorption studies performed after orthodontically induced tooth movement and has the major advantage of not depending on standardization of initial radiographs.

A digital Vernier caliper with accuracy of 0.001 was used in this study for measuring pretreatment and post treatment root length. The same instrument was used in previous studies and is more accurate for measuring root length.[69]

Intergroup comparison :

Comparing root resorption levels between non compensated class I malocclusion (Angle's class I malocclusion on class I skeletal base) and compensated class I malocclusion (Angle's class I malocclusion on class II skeletal base) have shown statistically significant difference in root resorption levels between compensated and non compensated class I malocclusion. Mean root resorption value of anterior teeth was 1.57 mm for non compensated class I malocclusion and 0.96 mm for compensated class I malocclusion. There was a positive statistically significant ($P = 0.01$) increase in root resorption levels of anterior teeth in non compensated class I malocclusion compared to compensated class I malocclusion. This is contrary to the previous studies[50,52], which have shown increased root resorption levels in compensated malocclusion compared to non compensated malocclusion. This variation could have been due to differences in severity of malocclusion between class I and class II skeletal base.

Comparing root resorption levels between non compensated class II division 1 malocclusion (Angle's class II division 1 malocclusion on class I skeletal base) and compensated class II division 1 malocclusion (Angle,s class II division 1 malocclusion on class II skeletal base), no statistically significant difference in root resoprption levels were found. This finding is in contrary to the results of the previous studies which have shown presence of statistically significant increase in root resorption level in compensated malocclusion compared to non compensated malocclusion.[50,52]

Comparing root resorption levels between class I and class II skeletal base irrespective of Angle's class I and class II division 1 malocclusion have shown no statistically significant difference in root resorption levels between class I and class II skeletal base. This finding is in contrary to the results of the previous studies which have shown presence of significant relationship between type of malocclusion and root resorption.[50,52]

Intragroup comparison :

Comparing root resorption levels between Angle's class I and class II division 1 malocclusion on class I skeletal base have shown absence of statistically significant difference in root resorption levels. This finding supports the results of the previous studies which have shown absence of statistically significant difference in root resorption levels between Angle's malocclusion.

Comparing root resorption levels between class I and class II division 1 malocclusion on class II skeletal base have shown statistically significant difference in root resorption levels (P = 0.001). Mean root resorption value of anterior teeth in this study was 0.96 mm for class I malocclusion and 1.78 mm for class II division 1 malocclusion group. This is contrary to the results of the previous studies which have found absence of statistically significant difference in root resorption levels between Angle's class I and class II division 1 malocclusion.[52,68]

Correlation :

There were some interesting findings on the relationship between overjet, overbite, treatment duration, treatment mechanics and root resorption.

Age and gender did not have a significant correlation with resorption as found in other studies. The present study found a positive statistically significant correlation of root resorption with initial overjet ($P = 0.01$) and initial overbite ($P = 0.002$). This correlation was in agreement with several other studies in the literature demonstrating that intrusion can be considered as a predictive factor for resorption.[13,23,27,61]

The present study showed a positive statistically significant correlation ($P = 0.001$). This finding was in agreement with other studies demonstrating that longer the treatment duration, the more severe the root resorption.[2,8,29]

The present study showed a statistically significant correlation between root resorption and treatment mechanics ($P < 0.001$). The patients treated with combined retraction and intrusion mechanics had statistically greater root resorption than those treated with retraction mechanics alone. These findings supports the results of the previous studies.[2,13,32,34] This research confirms that a larger degree of root resorption and a greater degree of resorbed teeth are expected when intrusion mechanics are associated with retraction mechanics.

SUMMARY AND CONCLUSION

External apical root resorption is a relatively common iatrogenic outcome of orthodontic treatment, which can be seen in routine panoramic radiographs. The present study was done in the department of Orthodontics and Dentofacial Orthopaedics, Tamil Nadu government dental college and hospital, Chennai. A total of 80 patients in the age range of 15 – 25 years of both genders who had undergone orthodontic treatment with fixed appliance mechanotherapy were included in this study based on inclusion and exclusion criteria. Pre treatment and post treatment panoramic radiographs were used to evaluate root resorption.

Following conclusions were derived from this study,

1. Statistically significant increase in root resorption level was found in non-compensated class I malocclusion compared to compensated class I malocclusion.
2. No statistically significant difference in root resorption level was found between compensated and non-compensated class II division 1 malocclusion.
3. No statistically significant difference in root resorption levels of anterior teeth was found between Angle's class I and class II division 1 malocclusion on class I skeletal base.
4. Age and Gender was not an influencing factor in root resorption.
5. Overjet and overbite had statistically significant correlation with post treatment root resorption.

6. There was a statistically significant correlation between treatment duration and post treatment root resorption; the longer the duration, the more severe the root resorption.
7. Treatment mechanics had a statistically significant correlation with post treatment root resorption. It was found that increased amount of root resorption occurs when intrusion mechanics were associated with retraction mechanics.

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